between vertices, and triangulation is used to create surfaces. However, it is desirable to represent free-form surfaces. A well-known way of doing this is to use surface splines as described e.g. in Jörg Peters, Biquadratic C^1-surface splines over irregular meshes, Computer Aided Design Volume 27 Number 12, December 1995, pp. 895-903, 1995.

A B-spline is a smooth free-form surface defined by a set of mxn control vertices in a regular mesh. A complex surface can be constructed by creating a mesh of control vertices. In order to reduce the number of control vertices necessary for representing a surface with a number of local changes or deformations, a method of using hierarchical B-splines is known from David Forsey, Hierarchical B-splines, published on the Internet at http://www.cs.ubc.ca/nest/imager/contributions/forsey/dragon/hbsplines.html. This technique consists of adding a B-spline patch to the region around the deformation, necessitating the addition of control vertices only to this patch.

SUMMARY OF THE INVENTION

Common to the prior art solutions is that they do not provide an effective data structure that allows efficient interaction between objects, and dynamic change of topology and geometry as a result of such interactions. The present invention aims at providing a method and a data structure that facilitates fast and efficient local interaction between 3D-objects, and fast and efficient local refinement or local deformation of the 3D-object descriptions.

The present invention is based on the use of generalized maps (G-maps) in order to describe the mesh topology, and on a smooth geometric description of the surface superimposed on this mesh.

Generalized maps (G-maps) is a type of generalized boundary representation model where the basic topological element of the topological map is the dart, a semi edge of a graph. A map is defined by a set of darts, D, and a set of involutions (α_0, α_1, ..., α_n). Each involution "α_i" describes the links between darts corresponding to a dimension "i". In 3-dimensional space, these relationships are used to subdivide an object into topological volumes (α_3), a volume into topological faces (α_2), a face into topological edges (α_1), and an edge into topological vertices (α_0).

Spatial representation of a 3-dimensional topological map consists in associating geometric entities with cells. Points in space are associated with vertices (0-cells), curve arcs are associated with edges (1-cells), surfaces are associated with faces (2-cells), and geometric volumes are associated with topological volumes (3-cells). These associations constitute the embedding of geometrical data in the topological map.

CLAIMS

1. Method for creating an irregular mesh description and an embedded geometric description in a computer graphics system, comprising:

receiving topological input data representing vertices and faces of the mesh,

creating a G-map representation of the topology of said mesh based on said input data,

associating coordinates in space with the vertices of said mesh, and

creating a smooth geometric description from said mesh and said coordinates.

2. Method according to claim 1, wherein the step of creating a geometric description comprises applying a subdivision algorithm repeatedly until a sufficiently smooth surface has been created.

3. Method according to claim 1, wherein the step of creating a geometric description comprises the step of creating a refined mesh based on said first mesh and said coordinates, using coordinates associated with the vertices of said refined mesh to compute control points, and using said control points to create surface patches associated with said first mesh.

4. Method according to claim 3, wherein said refined mesh is created by applying a mesh refinement algorithm, and where each patch of said first mesh is created as a surface spline associated with a quad of said first mesh.

5. Method according to one of the previous claims, wherein the step of creating a G-map comprises the steps of creating a set of darts each associated with one vertex and one face of said first mesh; and creating a number of involutions that establish associations between pairs of darts so that an α_0 involution links two darts associated with adjacent vertices but the same face, creating an edge, an α_1 involution links two darts associated with the same vertex and the same face, and an α_2 involution links two darts associated with the same vertex but adjacent faces, linking two adjacent faces.

6. Method according to one of the previous claims, wherein a local refinement of said first mesh is created by defining a second mesh corresponding with one or more quads of said first mesh, subdividing said quads of said first mesh into smaller quads of said second mesh and describing the topology of said second mesh with a second G-map representation.

7. Method according to claim 6, wherein said second G-map is linked to said first G-map through γ-links between darts on the different levels.

8. Computer system for creating an irregular mesh description and an embedded geometric description from input data, comprising:

input interface for receiving topological input data representing vertices and faces of the mesh,

processing means for creating a G-map representation of the topology of said mesh based on said input data and storing said representation in memory,

processing means for associating coordinates in space with the vertices of said mesh and storing said coordinates in memory,

processing means for creating a smooth geometric description from said mesh and said coordinates, and

output interface for outputting said smooth geometric description for representation on a display.

9. Computer system according to claim 8, wherein said means for creating a geometric description comprises processing means for applying a subdivision algorithm repeatedly until a sufficiently smooth surface has been created.

10. Computer system according to claim 8, wherein said means for creating a geometric description further comprises processing means for creating a refined mesh based on said first mesh and said coordinates, using coordinates associated with the vertices of said refined mesh to compute control points, and using said control points to create surface patches associated with said first mesh.

11. Computer system according to claim 10, wherein said means for creating said refined mesh is capable of applying a mesh refinement algorithm, and of creating each patch of said first mesh as a surface spline associated with a quad of said first mesh.

12. Computer system according to one of the claims 8 to 11, wherein said means for creating a G-map comprises means for creating a set of darts each associated with one vertex and one face of said first mesh; and means for creating a number of involutions that establish associations between pairs of darts so that an α_0 involution links two darts associated with adjacent vertices but the same face, creating an edge, an α_1 involution links two darts associated with the same vertex and the same face, and an α_2 involution links two darts associated with the same vertex but adjacent faces, linking two adjacent faces.

13. Computer system according to one of the claims 8 to 12, further comprising processing means for creating a local refinement of said first mesh by defining a second mesh corresponding with one or more quads of said first mesh, subdividing said quads of said first mesh into smaller quads of said second mesh and describing the topology of said second mesh with a second G-map representation.

14. Computer system according to claim 13, further comprising means for creating a link between said second G-map and said first G-map through links between darts on the different levels and storing these links in memory in a way that is associated with one or both G-map.

15. Computer system according to one of the claims 8 to 14, wherein the various processing means comprises a combination of computer program instructions and general purpose hardware.

16. Computer system according to claim 15, wherein said computer program instructions are stored on a persistent memory device in said computer system.

17. Computer program product comprising computer instructions that, when installed on a computer, makes said computer capable of performing the method of one of the claims 1 to 7.

18. Computer program product according to claim 17, stored on a computer readable medium.

19. Computer program product according to claim 18, wherein said computer readable medium is a CD-ROM or DVD-ROM.

20. Computer program product according to claim 18, wherein said computer readable medium is a magnetic or magneto-optical storage medium.

21. Computer program product according to claim 17, carried on a propagated signal.

22. Method for arranging data in order to describe an irregular mesh topology and an embedded geometric description comprising creating

a first data structure of a first type representing a G-map representation of a topological mesh and containing an arbitrary number of references to a second type of data structure,

an arbitrary number of data structures of a second type representing darts of the G-map, containing references to three other data structures of said second type, said references representing α-involutions of the G-map representation,

and three references to data structures of a third, a fourth and a fifth type, respectively,

an arbitrary number of data structures of a third type representing vertices of the G-map, containing a reference to a data structure of a sixth type,

an arbitrary number of data structures of a fourth type representing quads of the G-map, containing a reference to a data structure of a seventh type,

an arbitrary number of data structures of a fifth type representing faces of the G-map, containing a reference to a data structure of an eight type,

an arbitrary number of data structures of a sixth type, being or including a variable containing the coordinates of a point in three dimensional space associated with a vertex of said G-map,

an arbitrary number of data structures of a seventh type, containing a description of a geometrical patch associated with a quad of said G-map, and

an arbitrary number of data structures of an eight type, containing a variable representing the coordinates of a point in three dimensional space associated with a face of said G-map.

23. Method according to claim 22, wherein the creation of said data structures of the fourth type further includes creating one variable representing a vertex of a second mesh derived from the coordinates of the vertices of said first G-map mesh and one variable representing coefficients used for deriving said vertex of said second mesh from said coordinates of the vertices of said first G-map mesh.

24. Method according to claim 23, further comprising the creation of local refinement of said irregular mesh topology and said embedded geometric description by creating

a second data structure of said first type representing a second G-map representation of a refined topological mesh,

in at least some of the data structures of the second type referred to by said first data structure of the first type, a reference to a data structure of said second type referred to by said second data structure of said first type, thus creating a reference from said first G-map representation of a topological mesh to said second G-map representation of a refined topological mesh.

25. Method according to claim 24, wherein at least some of the data structures of the second type contains references to two other data structures of said second type, one that is part of a G-map representation of a refined topological mesh and one that is part of a G-map representation of a coarser topological mesh.

26. Method according to claim 24 or 25, wherein the creation of data structures of the sixth type as part of the second G-map representation of a refined topological mesh includes storing, in the variable that is or is part of this data structure of the sixth type, the value found in the variable representing a vertex of a second mesh in an associated data structure of the fourth type in said first G-map representation of a topological mesh.

27. Method according to one of the claims 22 – 26, wherein at least some of the references contained in the data structures are empty due to incompleteness of one or more of the topological meshes.

28. Method according to one of the claims 22 – 27, wherein some of said data structures are included as parts of a larger data structure.

29. Method according to one of the claims 22 – 28, wherein at least some of the data structures are objects and at least some of the references are pointers.

30. Method according to one of the claims 22 – 29, wherein the data structures of the third, fourth and fifth type are objects that inherit characteristics from a common class.

31. Method according to one of the claims 22 – 30, wherein all created data structures are stored in a computer memory for access by a data processing system.

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Geir WESTGAARD, et al.
Attorney Docket No. 03438.0111-00000

ANNEXES TO THE

PRELIMINARY EXAMINATION REPORT

(ARTICLE 34 AMENDMENTS)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

REQUEST FOR SUBSTITUTION OF REPLACEMENT SHEETS

Please substitute the attached replacement sheets 2-2A of the Article 34 Amendments for sheet 2 of the specification in the as-filed PCT application and sheets 20-24 of the claims containing the Article 34 Amendments for sheets 20-24 of the claims in the enclosed as-filed PCT application. It is respectfully requested that the specification and claims in the substitute sheets be examined during examination of the patent application. Claims 1-26 are currently pending.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW,
GARRETT & DUNNER, L.L.P.

Dated: January 28, 2005

By: ______________________
Ernest F. Chapman
Reg. No. 25,961

EFC/FPD/rac